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ABSTRACT

This paper presents a summary of action research investigating statistics students' understandings of the sampling distribution of the mean. With four sections of an introductory Statistics in Education course (n=98 students), a computer simulation activity (R. delMas, J. Garfield, and B. Chance, 1999) was implemented and evaluated to show students the sampling distribution "in action," as recommended by many authors and statistics professors. Assessments after the activity point to clear deficiencies in student understanding, such as not understanding how sample size affects the shape and variability of sampling distributions. With the addition of the computer simulation, the understandings of many students are still incomplete. This was most evident as the instructor moved forward in class to introduce inferential statistics. The paper discusses some of the deficiencies noted in student understandings and how the action research cycle will continue to work on these deficiencies. The posttest is attacned. (SLD)

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ED 458 282

RUNNING HEAD: TEACHING SAMPLING DISTRIBUTIONS

Improving Statistics Education Through Simulations:

The Case of the Sampling Distribution

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Paper Presented at the Annual Meeting of the

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Abstract

This paper presents a summary of action research I am doing investigating statistics students' understandings of the sampling distribution of the mean. With 4 sections of an introductory Statistics in Education course (n = 98 students), I have implemented and evaluated a computer simulation activity (delMas, Garfield, & Chance, 1999) to show students the sampling distribution "in action," as recommended by many authors and statistics professors. Assessments after the activity point to clear deficiencies in student understanding, such as not understanding how sample size affects the shape and variability of sampling distributions. With the addition of the computer simulation, students' understandings are still incomplete. This is most evident as I move forward in class and introduce inferential statistics. My results discuss some of the deficiencies I have identified in student understandings. Also included is a discussion of how the action research cycle will continue to work on these deficiencies.

One of the main challenges I (and many other statistics professors) find in teaching introductory educational statistics is how to present abstract topics such as statistical inference and sampling distributions (Dyck & Gee, 1998; Wybraniec & Wilmoth, 1999). Many students find these theoretical ideas difficult to grasp; assessment items I have used to check their understanding of these topics confirm this fact. I recently decided to take an action research approach to pinpointing the specific difficulties students have and finding alternative teaching, practice, and assessment methods for helping students overcome these difficulties. This paper presents two of the phases of an action research study I am conducting to change how I teach and assess students about the *sampling distribution*, perhaps the most abstract concept in introductory statistics (Dyck & Gee, 1998; Garfield, delMas, & Chance, 1999; Wybraniec & Wilmoth, 1999).

This paper specifically focuses on addressing the question of whether or not the computer simulation does increase introductory statistics students' understanding of (a) the Central Limit Theorem, and (b) the behavior of sampling distributions.

Action Research Model

Even though specific steps in the action research process have been described in different ways, researchers generally agree that the process is iterative or cyclical (Mills, 2000). I chose as my model the cycle proposed by Kemmis (1990) (see Appendix A for an adaptation of this cycle). This paper follows a format similar to Kemmis' model, using the following sections (as described by Mills (2000)):

(1) *Reconnaissance*: what is the current situation, what do I think is impacting the situation, and what does the literature have to say?

(2) *General Plan and First Action Step*: what is my overall strategy for addressing the situation, and what will my first step in the strategy be?

(3) *Monitoring*: what did I learn during the implementation of the first step, and how did I learn it?

(4) *Evaluation*: was the first step enough, and if not, what will my second step be? Why?

Reconnaissance

My statistics classroom is no different from many of the classrooms I hear and read about: students just do not grasp the idea of a sampling distribution. For five years, this has been the one experience I try to improve or change nearly every time I teach it. Understanding *why* students are not grasping this concept relies first on understanding *what* specifically about the concept they do not understand. At what parts during the introduction to sampling distributions do students "lose it?"

When introducing sampling distributions to my students, I stress the importance of this topic to topics we will cover over the next few weeks (i.e., hypothesis tests and confidence intervals). I repeat again and again that understanding the sampling distribution ideas we are covering is fundamental to understanding these upcoming topics (Aberson, Berger, Healy, Kyle, & Romero, 2000; Wybraniec & Wilmoth, 1999; Yu, et al, 1995). My intent is to indirectly (or perhaps directly, depending on how they take it) implore students to pay attention, ask questions, and review class notes on their own to check their understandings. What I have found, however, is that questions students ask in class are more of the type "what page are we on?" or "what is that green thingy again?" instead of questions about the actual content. Further, assignments I give to students to check their understanding after the class generate miserable results. At the point when they are asked to apply what they have heard to a real problem scenario, students find (and I find) what they heard did not make sense, or if it did make sense, students cannot immediately form a stable understanding of what it is they heard.

General Plan

The lack of understanding demonstrated by these assignments led to my decision to find alternative ways to introduce the topic of sampling distributions to students in class. As I reviewed the current literature on teaching sampling distributions, this coincided with a review of several websites and computer programs created for this purpose. I selected the *Sampling SIM* materials created by delMas, Garfield, and Chance (1999) for three reasons:

(1) The materials include extensive instructions for the student or instructor to follow, including a scrapbook for notes and a large number of review questions.

(2) The program software is easy to download onto either a Mac or PC platform, and, with the accompanying instructions, it is easy to use.

(3) The authors include several reports of their experiences with the program, one of which suggested replication at other institutions.

It was this third reason, the call for replication, the led to the formalization of my action research plan into a replication study based on the study reported in delMas, Garfield, and Chance (1999). These materials are available on the Internet at: http://www.gen.umn.edu/faculty_staff/delmas/stat_tools/index.htm

First Action Step

Setting

The setting for this study included four sections of a graduate-level introductory Statistics in Education course in the College of Education at Bowling Green State University. One section met Spring 2001 (n = 20), one section met Summer II 2001 (n = 25), and two sections met Fall 2001 (n = 53), for a total sample size of 98 students. Many of the students are employed full-time and returning to earn their Master's degrees in a variety of education fields, including College Student Personnel, Curriculum and Instruction, Counseling, Marketing and Business Education, Higher Education, and Educational

Administration. Students in non-education fields are also represented, including: Nutrition; Human Movement, Sports, and Leisure Studies; and Communication Studies. Mean age for students in the four sections discussed is 31.3 years (s = 9.0). Only students who gave consent for their assessments to be used for research data are included here.

One week in each term, I introduce students to the sampling distribution concept by first reviewing what we have learned already about raw data distributions. We then spend some time distinguishing between a sample and a population, and we also review basic probability notions necessary to continue forward. Then, a hands-on demonstration of drawing multiple samples, recording statistics for each sample, and plotting those statistics is conducted using manipulatives such as playing cards, M & M's, slips of paper with numbers on them representing test scores, and dice.

Finally, students are introduced to the concept of sampling distribution itself, as a distribution of sample statistics similar to what we had just covered for raw data. I direct students' attention to the mean as our statistic of choice for the time being, and we again review each step in the process specifically discussing sample means (i.e., drawing multiple samples, recording means, plotting means, probability of various values, etc.).

The following week, I introduce the *Sampling SIM* demonstration to students as an instructor-led exercise. This is one change I chose to make from the original authors' study, in which students complete the demonstration individually but with supervision. My choice was based on prior course sections in which students' experience with computers was highly variable, as well as on the hope that students would benefit more from group discussion than individual work. (delMas, Garfield, and Chance (1999) indicate this is one of the aspects of the demonstration they are evaluating for change). The following week, students are given the post-test and then we begin our discussion of one-sample hypothesis testing.

Instrumentation

The data reported here come from one instrument: the post-test accompanying the *Sampling SIM* software (see Appendix B). The post-test consists of 20 multiple-choice and 4 true-false questions about sampling distributions. All but five of these questions can be coarsely categorized into three sets: (a) two questions about the mean of the sampling distribution, (b) seven questions about the shape of the sampling distribution, and (c) ten questions about the variability of the sampling distribution. Four questions ask students to select appropriate sampling distribution histograms for various sample sizes, a task that incorporates decisions about both shape and variability. The very first question asks students whether 5 or 20 items in a sample will result in a more accurate estimate of the population mean. Ninety percent of the students in the current study answered this first question correctly. Students were given the post-test one week following the class session in which we went through the simulation. Students completed the post-test individually and without books or notes. Calculators were allowed.

Monitoring First Action Step

With the first action step in place, I now turn to the question of monitoring its effects. These results come from two sources: the post-test (to be described in the next section) and my own journal of observations and thoughts about the each of the evenings in which I presented the simulation. These journal observations generally run along three threads: (a) experience with the technological aspects of using the simulation, (b) observations of students' attentiveness, and (c) records of students' questions and comments during and after the simulation. These will be discussed further in the discussion section of the paper.

Attending to technology issues vastly improves the simulation experience for students. One semester I ran the software from a disk instead of the hard drive and the

down time was immense – leading to idle student chitchat and a rather boring and uneventful simulation. Lesson: run the software from a hard drive only (this would be the Summer I 2001 semester, which is why there is no data from that group). Having the classroom set-up to run a computer demonstration is also important. When I am assigned to classrooms without a hookup station to view computer screens, I have to find alternatives to make sure the room is ready to go. Working on this ahead of time prevents a delayed start on class day. It is also important to have printed and copied all the ancillary handouts and guides for students to follow along.

Observations and records of students' comments are also important to the process. Any classroom change should be directed at improving the students' learning experience. The simulation exercise is not a lecture, although I do interject at certain places to make sure students are all seeing the same image I am on the screen. I also watch for students to become disinterested, turn their attentions elsewhere, begin chatting amongst themselves, or other signs they are not paying attention. I informally monitor this type of behavior in any class, but with the room dark and my attentions on the screen and running the program, I seem to be more aware of them during the activity. Student questions and comments can also be monitored as a way to evaluate whether or not they are following along okay, what they are getting, and how they feel about the simulation as a classroom activity.

The interesting results from the post-test come in two forms, each of which will be presented here: (a) a simple description of questions missed on the post-test, and (b) patterns of responses across similar questions.

Individual Question Results

Table 1 summarizes response results to individual questions. Columns in the table differentiate among the four course sections included in this study. The most obvious result presented is that no question was answered correctly by every student. Still, most

percentages are high, indicating overall most students are able to at least recognize the correct responses to questions. The fact that no student answered every question correctly coupled with the fact that no question was answered correctly by every student makes it obvious that recognition alone does not lead to adequate understanding – students must be able to consistently apply this knowledge, and that did not happen on this post-test for any of the four sets of students.

Response Patterns Across Related Questions

One question that arose during analysis was whether or not students at least responded consistently to related questions. These results will be presented in two parts. First, Questions 4 and 5 on the post-test ask the student to respond to the same nine questions for two different population distributions (see Appendix B for these questions). If students' understandings are solid at this point, they should answer similarly on both sets (whether they respond consistently with the wrong response or with the right response). Second, patterns across the three categories of questions (shape, mean, variability) will be addressed to identify if one aspect of the Central Limit Theorem presented more problems than another.

delMas, Garfield, and Chance (1999), in their discussion of Questions 4 and 5 on the post-test, identified four different types of reasoning students may be demonstrating through their selection of various graph pairs for each question. Again, remember that students are given a population distribution and five "sampling distributions" (with the understanding that these are truly distributions of 500 sample statistics, not complete sampling distributions) of 500 samples. In Questions 4a and 5a students are asked to select the appropriate sampling distribution for 500 samples of size 4; in Questions 4e and 5e they are asked to select the appropriate sampling distributions for 500 samples of size 16. The four types of reasoning include:

Table 1

Percent of students correctly answering individual items on post-test.

Item	Category	Spring '01	Summer '01	Fall '01A	Fall '01B	All Students
1	N/A	100.0	92.0	82.1	88.0	89.8
2	Variability	10.0	21.7	28.6	44.0	27.1
3	Variability	26.3	16.7	28.6	56.0	32.3
4a	N/A	00.0	00.0	21.4	16.0	10.3
4c	Shape	55.0	79.2	85.7	84.0	77.3
4d	Variability	65.0	39.1	42.9	64.0	52.1
4e	N/A	45.0	58.3	71.4	60.0	59.8
4g	Shape	93.1	83.3	92.9	96.0	90.7
4h	Variability	75.0	79.2	71.4	84.0	77.3
4i	Variability	63.2	91.7	89.3	96.0	86.5
5a	N/A	22.2	8.3	10.7	12.0	12.6
5c	Shape	73.7	83.3	78.6	80.0	79.2
5d	Variability	68.4	29.2	46.4	56.0	49.0
5e	N/A	47.4	70.8	71.4	60.0	63.5
5g	Shape	89.5	87.5	100.0	92.0	92.7
5h	Variability	78.9	79.2	75.0	88.0	80.2
5i	Variability	84.2	87.5	88.9	92.0	88.4

Table 1

Percent of students correctly answering individual items on post-test (continued).

Item	Category	Spring '01	Summer '01	Fall '01A	Fall '01B	All Students
6	Variability	45.0	58.3	60.7	68.0	58.8
7	Mean	55.0	45.8	39.3	52.0	47.4
8	Shape	75.0	66.7	67.9	64.0	68.0
9a	Mean	65.0	69.6	60.7	68.0	65.6
9b	Shape	55.0	54.2	60.7	84.0	63.9
9c	Shape	85.0	91.3	92.9	96.0	91.7
9d	Variability	95.0	95.7	96.3	96.0	95.8

Note 1: Questions 4b, 4f, 5b, and 5f are excluded because they were not right/wrong questions; they asked students to indicate how confident they were in their selections.

(1) Correct reasoning, in which the correct distributions are selected for both sample sizes,

(2) Good reasoning, in which the student selects the correct distribution for one sample size and an appropriate but incorrect distribution for the other (i.e., they do select a distribution with less variability for the higher sample size, even if it is the wrong distribution),

(3) Larger to smaller reasoning, in which students select distributions with larger variability for the smaller sample size but with incorrect shapes, and

(4) Smaller to larger reasoning, in which students select distributions with smaller variability for smaller sample sizes.

For the current study, results for the various types of reasoning are presented by question in Table 2.

Table 2 indicates that most students are able to at least recognize two facts: (a) what larger and smaller variability look like in a histogram, and (b) that those histograms with smaller variability should be selected when the sample size goes up from 4 to 16. Only 2 students demonstrated correct understanding for both questions, and another 15 students demonstrated correct reasoning either Question 4 or Question 5, but not both.

Consistency Among Questions Addressing Variability

One of the CLT concepts addressed by the post-test is the variability of the sampling distribution. One pattern I noticed during data analysis was that students are *not* consistent as they answer all of these questions. For example, if students selected Distributions B, C, or D in Question 4a, they should have also indicated in Question 4d that they expect the variability to be less than the population. Only 29 (30.2%) students who chose these graphs also indicated they expected the sampling distribution to have less variability than the

Table 2.

Frequency of four types of reasoning demonstrated by responses to Questions 4 and 5[a]

Type of Reasoning	Question 4	Question 5	Both
Correct	7.9[a]	12.8	2.3
Good	28.1	11.7	2.3
Larger to Smaller	51.7	70.2	46.6
Smaller to Larger	9.0	4.3	3.4

[a]Note: Percents do not add up to 100 because some students' response patterns were not clearly identified as any of the four listed in the table.

population. Twenty-five students (26.0%) selected Graphs A or E for Question 4a, and they too were consistent (although incorrect) in expecting the variability of the sampling distribution to be the same as that of the population. The remaining 42 students (43.8%) chose graphs and expectations in 4a and 4d respectively that were inconsistent (e.g., they chose a graph with less variability but indicated they expect more variability than in the population). These last 42 students are of primary concern, as they are either (a) not able to consistently apply their knowledge, (b) do not recognize "smaller" or "larger" variability in a histogram (which implies a lack of knowledge to apply), or (c) are not committed to the exercise enough to pay attention to their responses.

Even more interesting is the switch from a sample size of 4 to a sample size of 16. Here, 75 students (77.3%) consistently selected a histogram in Question 4e with smaller variability that matched their expectation given in Question 4h. Only two students (2.1%) selected a graph with the same variability and also indicated that as their expectation. The remaining 20 students (20.6%) were inconsistent. These numbers are very different from those for a sample size of 4. One potential explanation is that students do not yet see that even with sample sizes of 4, the sampling distribution will begin to look like a normal distribution. Thus, their responses in Questions 4a and 4d are less certain than those in Questions 4e and 4h, where they are more convinced that a higher sample size yields a more normal curve with less variability than the original population.

These shifts in reasoning are considered clear evidence that whatever understandings students have formed at this point, they are not stable. Stable understandings are assumed to lead to consistent response patterns, which not even half of these students demonstrated. These results are almost perfectly replicated when we switch to Question 5 (which switches the focus from a positively skewed population to an erratic one), indicating that this may not be simply a function of the type of population distribution presented.

Another section of the post-test that addresses the variability of the sampling distribution is Questions 6 and 9d. Here, students are asked first to indicate that the standard deviation of the mean will have less variability than the original population (Question 6), and then recognize the formula for the standard error (Question 9d). If students understand the variability aspect of sampling distributions, they should answer consistently correct on both of these questions. Fifty-four students (56.8%) did so, with another 38 students (40.0%) answering these questions inconsistently (typically missing the application question but correctly recognizing the formula in 9d). The remaining students answered these questions consistently, but their answers were incorrect. Even though the data analysis could go on across a variety of other questions, the results consistently point to one fact: students apparently recognize the "facts" of the Law of Large Numbers and the Central Limit Theorem. However, many of those students cannot apply these facts to real situations.

Evaluation and Second Action Step

The main question addressed in this paper was whether or not the computer simulation activity was helping increase student understanding of the behavior of the sampling distribution and of the Central Limit Theorem (CLT). My impressions are that the computer simulation *does* reinforce the various aspects of the CLT for some students, but there is still a large group of students who are not convinced after the simulation. For the four true/false items, which each ask about the components of the CLT, only 45 students responded correctly to all four. This leaves 57 students with inadequate knowledge. The more striking result is that even students who do recognize these rules, many are not able to apply them to various situations. del Mas, Garfield, and Chance (1999) found similar results and drew similar conclusions about the sufficiency of the demonstration. Obviously more work is needed before and after the demonstration – one question is how much? When do we stop?

Did the computer simulation work? Not completely. This is consistent with other authors who have investigated simulations in statistics classrooms (Hodgson & Burke, 2000; Well, Pollatsek, & Boyce, 1990). Still, based on informal student reactions and my own observations, I think it does *help*. As we moved forward in each of these course sections to begin hypothesis testing, some students remembered "seeing" a sampling distribution on the computer screen and noticed that the same idea is now taking place with hypothesis testing. I always hear a few students say, "This is just like what we saw on the computer, right? So if I have this for the hypothesis test, then the same thing should happen, right?" This is encouraging to me, and is enough reason to for me to continue exploring the simulation activity and its use in the classroom.

The next cycle in the action research study will be to work with many more examples with numbers after the computer simulation is done, to reinforce each aspect of the Central

Limit Theorem. Hopefully, extra "real-world" examples will increase the stability of students' understandings, which we will hopefully see through an improvement in post-test performance.

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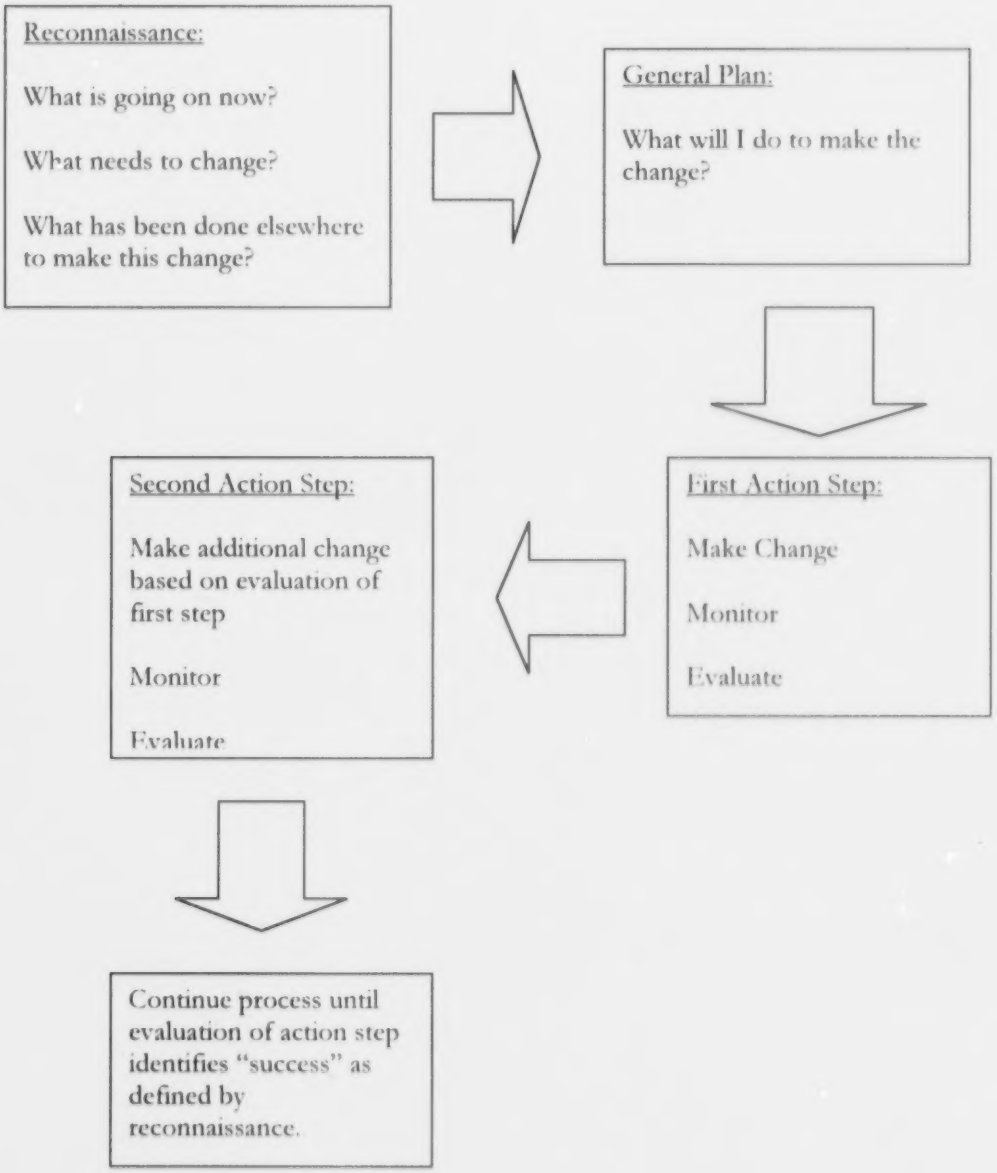
Appendix A

Adaptation of Action Research Cycle Proposed by Kemmis (1990)


Reconnaissance:
What is going on now?
What needs to change?
What has been done elsewhere to make this change?
General Plan:
What will I do to make the change?
First Action Step:
Make Change
Monitor
Evaluate
Second Action Step:
Make additional change based on evaluation of first step
Monitor
Evaluate
Continue process until evaluation of action step identifies "success" as defined by reconnaissance.

Appendix B

Sampling Distributions Posttest

Name _____ Date _____

1. In a geology course, students were asked to determine the weight of rock samples. One instructor asked her students to weigh a rock several times on the same scale. This rock is known to weigh exactly 1000 grams. However, the scale is not completely accurate and sometimes it is off in either direction by 25 grams or less. After a lot of practice, one student weighed the rock 20 times, then computed and recorded the average of the 20 weighings. After a lot of practice, a second student weighed the rock 5 times, then computed and recorded the average of the five weighings.

   How would you expect the average weight recorded by the first and second student to compare? (circle one)

   a. The student who weighed the rock 20 times would have a more accurate average.
   b. The student who weighed the rock 5 times would have a more accurate average.
   c. Both averages would be equally accurate.
   d. It is impossible to predict which average would be more accurate.

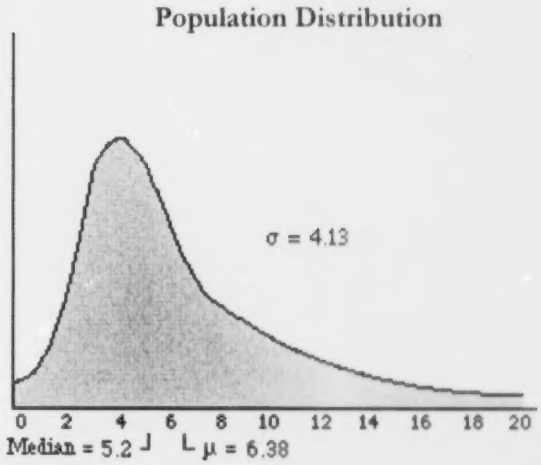
2. Weight is a measure that tends to be normally distributed. Suppose the mean weight of all women at a large university is 135 pounds, with a standard deviation of 12 pounds. If you were to randomly sample 9 women at the university, there would be a 68% chance that the sample mean weight would be between: (circle one)

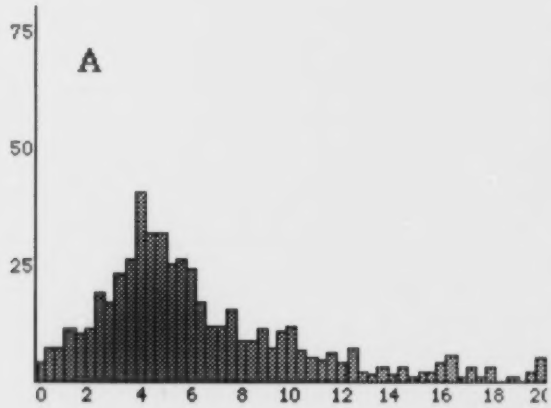
   a. 119 and 151 pounds.
   b. 125 and 145 pounds.
   c. 123 and 147 pounds.
   d. 131 and 139 pounds.
   e. 133 and 137 pounds.

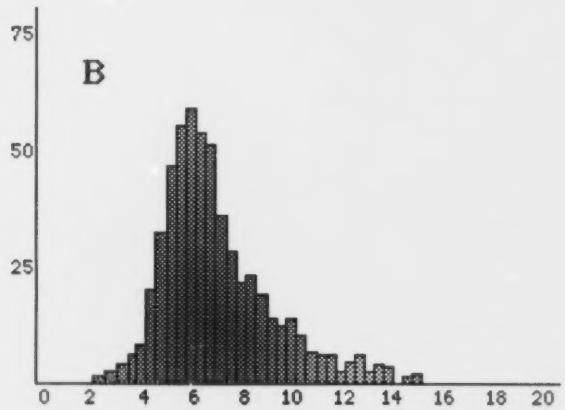
3. If you took a random sample of 36 university women from the population described in question 2 above, there would be a 68% chance that the sample mean weight would be between: (circle one)

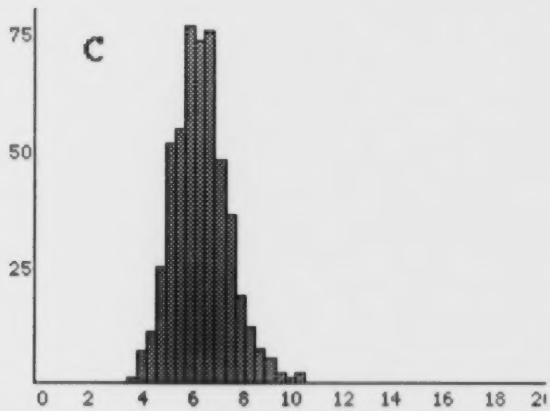
   a. 119 and 151 pounds.
   b. 125 and 145 pounds.
   c. 123 and 147 pounds.
   d. 131 and 139 pounds.
   e. 133 and 137 pounds.

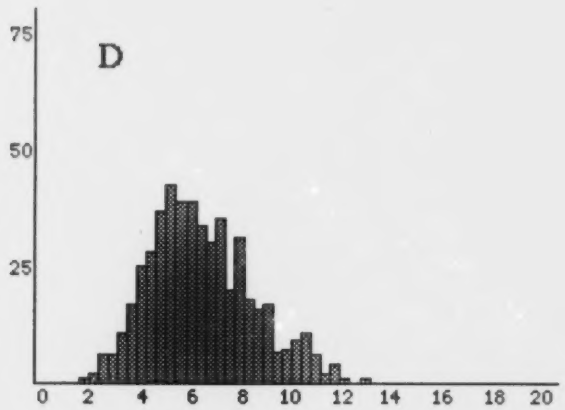
4. The distribution for a population of test scores is displayed below on the left. Each of the other five graphs labeled A to E represent possible distributions of sample means for random samples drawn from the population.

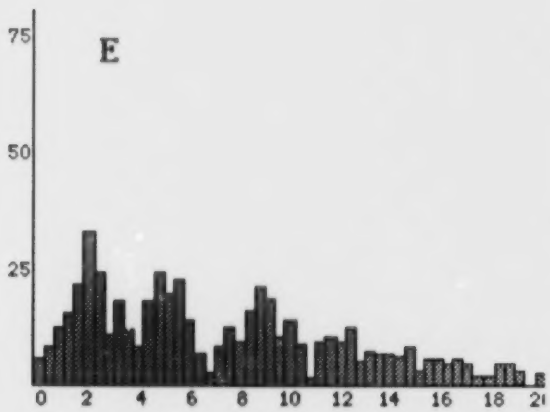












4a) Which graph represents a distribution of sample means for 500 samples of size 4?

(circle one) A B C D E

4b) How confident are you that you chose the correct graph? (circle one of the values below).

20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%

Answer each of the following questions regarding the sampling distribution you chose for question 4a.

4c) What do you expect for the shape of the sampling distribution? (check only one)

_ Shaped more like a NORMAL DISTRIBUTION.

_ Shaped more like the POPULATION.

Circle the word between the two vertical lines that comes closest to completing the following sentence.

4d) I expect the sampling distribution to have	less the same more	VARIABILITY than /

4e) Which graph do you think represents a distribution of sample means for 500 samples of size **16**?

(circle one) A B C D E

4f) How confident are you that you chose the correct graph? (circle one of the values below).

20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%

Answer each of the following questions regarding the sampling distribution you chose for question 4e.

4g) What do you expect for the shape of the sampling distribution? (check only one)

_ Shaped more like a NORMAL DISTRIBUTION.

_ Shaped more like the POPULATION.

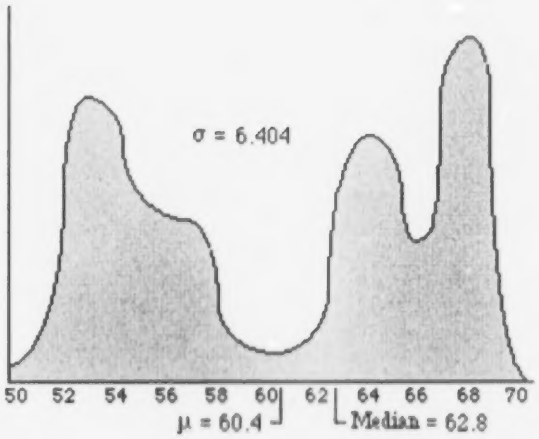
Circle the word between the two vertical lines that comes closest to completing each of the following sentences.

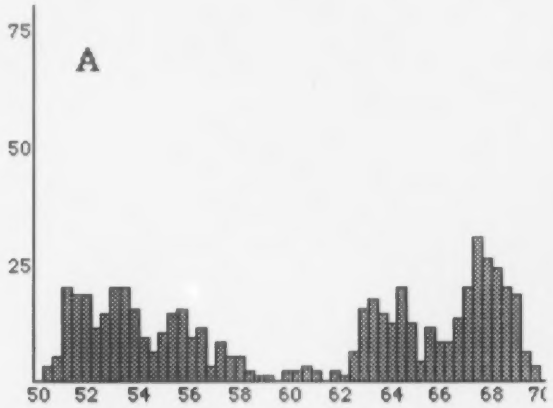
4h) I expect the sampling distribution to have as the POPULATION	less the same more	VARIABILITY than /

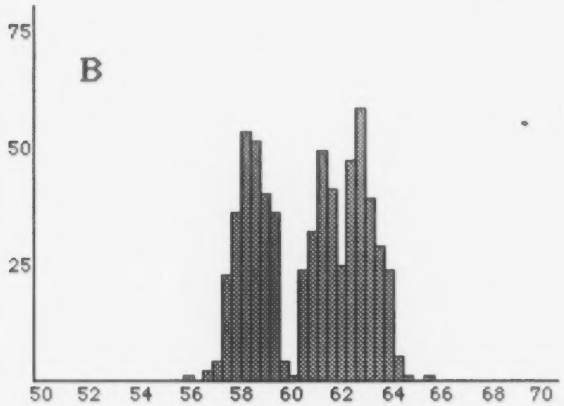
4i) I expect the sampling distribution the sampling distribution I chose for question 4e to have	less the same More	VARIABILITY than / as for question 4a.

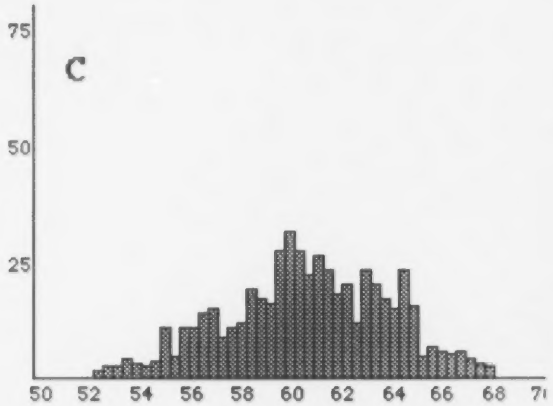
5. The distribution for a third population of test scores is displayed below on the left. Each of the other five graphs labeled A to E represent possible distributions of sample means for random samples drawn from the population.

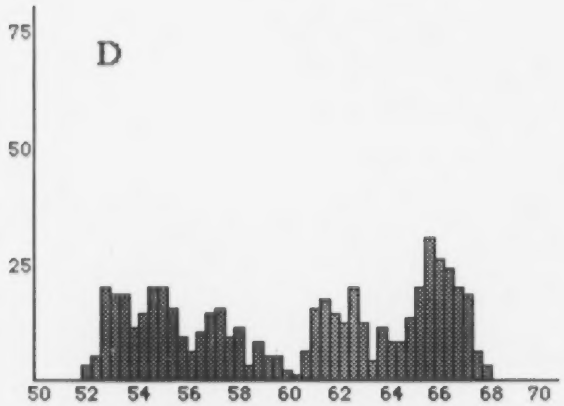
Population Distribution

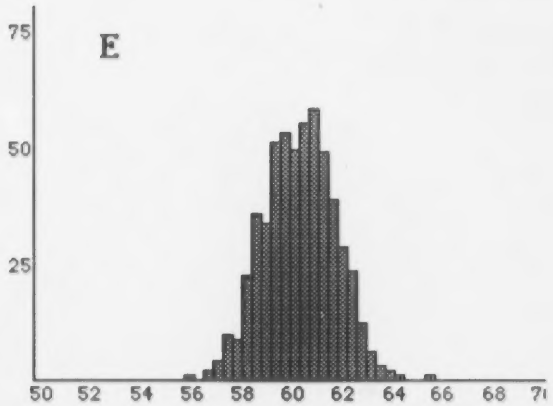












5a) Which graph represents a distribution of sample means for 500 samples of size 4?

(circle one) A B C D E

5b) How confident are you that you chose the correct graph? (circle one of the values below).

20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%

Answer each of the following questions regarding the sampling distribution you chose for question 5a.

5c) What do you expect for the shape of the sampling distribution? (check only one)

_ Shaped more like a NORMAL DISTRIBUTION.

_ Shaped more like the POPULATION.

Circle the word between the two vertical lines that comes closest to completing the following sentence.

5d) I expect the sampling distribution to have	less the same more	VARIABILITY than /
as the POPULATION		

5e) Which graph do you think represents a distribution of sample means for 500 samples of size **16**?

(circle one) A B C D E

5f) How confident are you that you chose the correct graph? (circle one of the values below).

20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95% 100%

Answer each of the following questions regarding the sampling distribution you chose for question 5e.

5g) What do you expect for the shape of the sampling distribution? (check only one)

_ Shaped more like a NORMAL DISTRIBUTION.

_ Shaped more like the POPULATION.

Circle the word between the two vertical lines that comes closest to completing each of the following sentences.

5h) I expect the sampling distribution to have VARIABILITY than / as the POPULATION	less the same more	

5i) I expect the sampling distribution the sampling distribution I chose for question 5e to have	less the same More	VARIABILITY than / as for question 5a.

6. The weights of packages of a certain type of cookie follow a normal distribution with mean of 16.2 oz. and standard deviation of 0.5 oz. Simple random samples of 16 cookies each will be taken from this population. The sampling distribution of sample average weight ($\bar{x}$) will have: **(CIRLCE ONE)**

   a. a standard deviation greater than 0.5

   b. a standard deviation equal to 0.5

   c. a standard deviation less than 0.5

   d. It's impossible to predict the value of the standard deviation.

7. The length of a certain species of frog follows a normal distribution. The mean length in the population of frogs is 7.4 centimeters with a population standard deviation of .66 centimeters. Simple random samples of 9 frogs each will be taken from this population. The sampling distribution of sample average lengths (the average $\bar{x}$) will have a mean that is: **(CIRLCE ONE)**

   a. less than 7.4

   b. equal to 7.4

   c. more than 7.4

   d. It's impossible to predict the value of the mean.

8. Scores on a particular college entrance exam are NOT normally distributed. The distribution of test scores is very skewed toward lower values with a mean of 20 and a standard deviation of 3.5. A research team plans to take simple random samples of 50 students from different high schools across the United States. The sampling distribution of average test scores (the average $\bar{x}$) will have a shape that is: **(CIRLCE ONE)**

   a. very skewed toward lower values.

   b. skewed toward lower values, but not as much as the population.

   c. shaped very much like a normal distribution.

   d. It's impossible to predict the shape of the sampling distribution.

9. Consider any possible population of values and all of the samples of a specific size (n) that can be taken from that population. Below are four statements about the sampling distribution of sample means. For each statement, indicate whether it is TRUE or FALSE.

   a. If the population mean equals μ, the average of the sample means in a sampling distribution will also equal μ. TRUE FALSE

   b. As we increase the sample size of each sample, the distribution of sample means becomes more like the population. TRUE FALSE

   c. As we increase the sample size of each sample, the distribution of sample means becomes more like a normal distribution. TRUE FALSE

   d. If the population standard deviation equals σ, the standard deviation of the sample means in a sampling distribution is equal to $\frac{\sigma}{\sqrt{n}}$. TRUE FALSE